Improved Harris Corner Detection for Chinese Characters

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***Abstract*—According to the characteristics of Chinese characters image, we propose an improved corner detection method based on Harris algorithm and the ideal of FAST to improve detection rate for next feature extraction in this paper. First, the image of Chinese characters is detected for corners using Harris algorithm. Second, using the FAST for reference, the false corners are removed. The corners founded lastly are the endpoints of line segments, providing the length of line segments for shape feature extraction. The proposed method is compared with several corner detection methods over a number of images. Experimental results show that the proposed method shows better performance in terms of detection rate being the base of feature extraction, but not best for running time.**

Keywords—Chinese characters; Corner detection; Harris

I. Introduction

Recovery of Chinese characters is of great significance to the inheritance and protection of Chinese characters. Feature Extraction and feature matching is the foundation of the recovery. Corner detection is an important approach for Feature Extraction and feature matching, such as the detected corner can offer the position of the interest point and further provide the length of line segment. Corner detection is also frequently used in motion detection, image registration, video tracking, image mosaicing, panorama stitching, 3D modeling and object recognition, so, a large number of corner detectors exist in this field. One of the earliest corner detection algorithms is the Moravec corner detection algorithm, which defines a corner to be a point with low self-similarity[1]. Harris and Stephens[2] then improved upon Moravec's corner detector, contributing a classic algorithm improved from different perspectives[3][4][5] for the corresponding application by the researchers later. There are some other algorithms such as LoG, DoG, DoH feature detection, SUSAN corner detector[6], Curvature Scale Space(CSS)[7][8] corner detection algorithm and so on. FAST(Features from Accelerated Segment Test)[9] is proposed by Edward Rosten and Tom Drummond, who proposes a machine learning of corner detection pertinently for video[10][11]. But, so far, almost no one corner detection method for Chinese characters. According to the characteristics of Chinese characters, this paper proposes a corner detection for Chinese characters based on Harris algorithm and FAST corner detector. The experiment proves that the new algorithm in this paper comparing with FAST and Harris has better efficiency.

II. Previous Work

The corner detection algorithms include the Moravec corner detection algorithm, the Harris corner detection algorithm, the Förstner corner detector, the level curve curvature approach, the SUSAN corner detector, CSS and FAST so on. Harris and FAST are introduced because of respective advantages.

A. Harris algorithm

Harris and Stephens improved upon Moravec's corner detector by considering the differential of the corner score with respect to direction directly, instead of using shifted patches. Without loss of generality, we will assume a grayscale 2-dimensional image is used. Let this image be given by I . Taking an image patch over the area (u,v) and shifting it by (x,y) , the weighted sum S of squared differences (SSD) between these two patches, is given by:

$$S(x,y)=\sum_u\sum_v w(u,v)(I(u+x,v+y)-I(u,v))^2 \tag{1}$$

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$(I(u+x, v+y)$ can be approximated by a Taylor expansion. Let I_x and I_y be the partial derivatives of I, such that

$$I(u+x, v+y) \approx I(u,v) + I_x(u,v)x + I_y(u,v)y \tag{2}$$

This produces the approximation

$$S(x,y) \approx \sum_u \sum_v w(u,v)(I_x(u,v)x + I_y(u,v)y)^2 \tag{3}$$

which can be written in matrix form:

$$S(x,y) \approx \begin{pmatrix} x & y \end{pmatrix} A \begin{pmatrix} x \\ y \end{pmatrix} \tag{4}$$

where A is the structure tensor,

$$A = \sum_u \sum_v w(u,v) \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix} = \begin{bmatrix} \langle I_x^2 \rangle & \langle I_x I_y \rangle \\ \langle I_x I_y \rangle & \langle I_y^2 \rangle \end{bmatrix} \tag{5}$$

This matrix is a Harris matrix, and angle brackets denote averaging (If a circular window or circularly weighted window, such as a Gaussian) is used, then the response will be isotropic.

A corner is characterized by a large variation of S in all directions of the vector (x, y). By analyzing the eigenvalues of A, this characterization can be expressed in the following way: A should have two "large" eigenvalues for an interest point. Based on the magnitudes of the eigenvalues, the following inferences can be made based on this argument:

- If $\lambda_1 \approx 0$ and $\lambda_2 \approx 0$ then this pixel (x, y) has no features of interest.
- If $\lambda_1 \approx 0$ and λ_2 has some large positive value, then an edge is found.
- If λ_1 and λ_2 have large positive values, then a corner is found.

Harris and Stephens note that exact computation of the eigenvalues is computationally expensive, since it requires the computation of a square root, and instead suggest the following function M_c, as

$$M_c = \lambda_1\lambda_2 - \kappa(\lambda_1 + \lambda_2)^2 = \det(A) - \kappa \operatorname{trace}^2(A) \tag{6}$$

where κ is a tunable sensitivity parameter.

Therefore, the algorithm does not have to actually compute the eigenvalue decomposition of the matrix A and instead it is sufficient to evaluate the determinant and trace of A to find corners, or rather interest points in general.

The Shi-Tomasi corner detector directly computes $\min(\lambda_1, \lambda_2)$, because under certain assumptions, the corners are more stable for tracking. The value of κ has to be determined empirically, and in the literature values in the range 0.04 - 0.15 have been reported as feasible.

Corners detected include correct corners, but also include too many false corners. In other words, missed detection rate is low but false detection rate is high. Running time of this algorithm is relatively long because of calculation based on pixels.

B. *FAST algorithm*

This is sufficiently fast that it allows on-line operation of the tracking system. A test is performed for a feature at a pixel *c* by examining a circle of 16 pixels (a Bresenham circle of radius 3) surrounding *p*. A feature is detected at *c* if the intensities of at least 12 contiguous pixels are all above or all below the intensity of *c* by some threshold *t*. This is illustrated in Figure1. The test for this condition can be optimized by examining pixels 1, 9, 5 and 13, to reject candidate pixels more quickly, since a feature can only exist if three of these test points are all above or below the intensity of *c* by the threshold.

Running time of this algorithm is short. Corners detected include correct corners and false corners. Correct detection rate and false detection rate are not high. There is missed detection rate but not high.

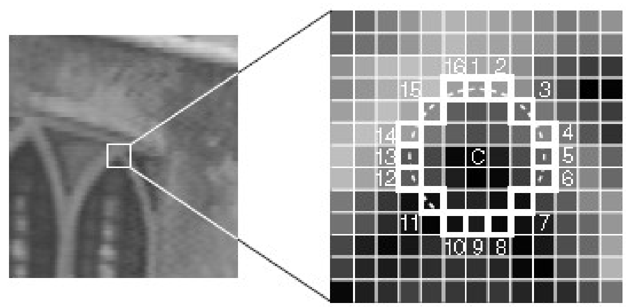


Fig. 1. FAST Feature detection in an image patch. The highlighted squares are the pixels used in the feature detection. The pixel at C is the centre of a detected corner: the dashed line passes through 12 contiguous pixels which are brighter than C by more than the threshold.

III. IMPROVED ALGORITHM

The pixel value of Chinese characters in the image is small comparing with the large pixel value of other region. So, target highlighted in the background is founded easily using edge detection. The corner is also detected effectively with various corner detection algorithms proposed by researchers for years. The hard work is how to find the endpoint of the line segment. The location of the endpoint is important to the length of lines as feature extraction in the image of Chinese characters and also important to image matching. Through many simulation experiments with different algorithms, Harris algorithm is proved effective with redundant corners. FAST algorithm can give good results in removing excess points. So, the new algorithm in this paper based on Harris algorithm borrows the idea of FAST. Algorithm steps as follows:

- RGB images of Chinese characters are changed to gray-level image.
- Corners in gray-level image of Chinese characters are firstly detected by improved Harris algorithm also called Shi-Tomasi corner detector. The value of κ is 0.08 empirically.
- The location of corners detected is saved. Corners detected include correct corners and false corners. There is almost no missed corners.
- Remove false corners: Circle of 16 pixels centered on the corner detected (saved) firstly is examined. A corner is detected lastly if the intensities of at least 12 contiguous pixels are all above the intensity of c by more than threshold t. If two out of the four pixels are both significantly brighter or both significantly darker than c (assuming the pixels are adjacent) in the optimized test, additional tests are required to examine pixels 2, 10, 6 and 14 in the same way. Then all corner detected (saved) are determined by the same way.

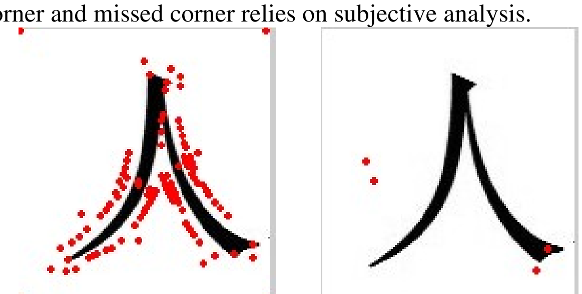
The set of threshold t: $I_i(i=1,...,M)$ is the pixel value of corner detected firstly, t is shown:

$$t=\frac{\sum_{i=1}^{M}255-I_i}{M} \tag{7}$$

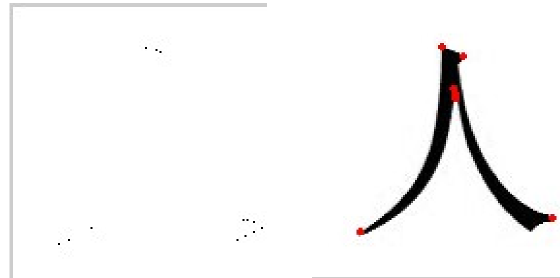
where M is the number of corners detected firstly and $I_i(i=1,...,M)$ is the pixel as corner firstly.

IV. Comparison

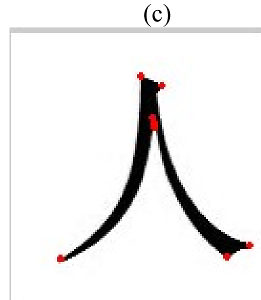
In this section, we compare the proposed method with four corner detectors (Harris, KP-Harris [4], SUSAN and FAST) in terms of two criteria such as detection rate and running time. The parameters of each corner detection method are tuned in order to detect the best fit corners for length of line segments. The parameter κ of Harris is 0.06. The test images include simple image as shown in Fig.2, middle-complex image as shown in Fig.3 and complex image as shown in Fig.4. Correct corner criterion depends on human experience about Chinese characters and the criterion of false corner and missed corner relies on subjective analysis.



(a) (b)



(c) (d)

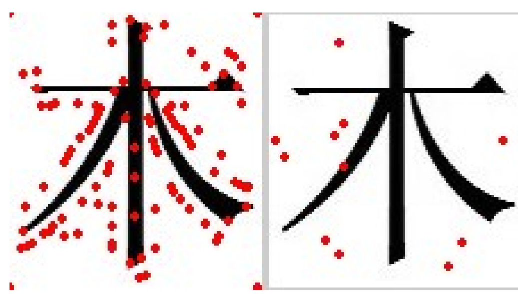


(e)

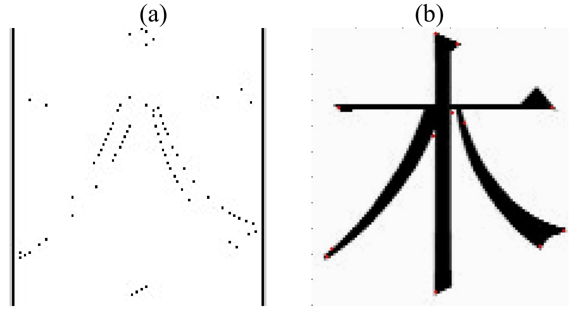
Fig. 2. Corner detection results for the simple image: (a) Harris, (b)KP-Harris, (c) SUSAN, (d) FAST, (e) the proposed method

TABLE I. Performance evaluation of "simple image"

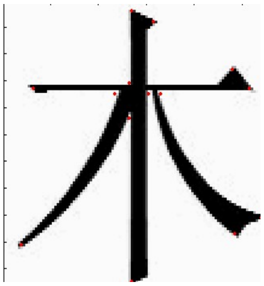
	Harris	KP-Harris	SUSAN	FAST	The proposed method
Correct corners	7	1	5	6	7
Missed corners	0	6	2	1	0
False corners	85	3	8	0	0
Running time(second)	1.108	0.297	6.334	0.467	1.125



(a) (b)



(c) (d)



(e)

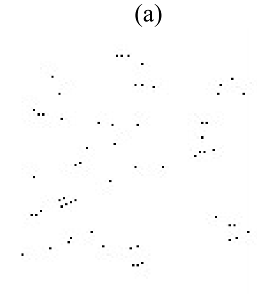
Fig. 3. Corner detection results for the middle-complex image: (a) Harris, (b)KP- Harris, (c) SUSAN, (d) FAST, (e) the proposed method

TABLE II. PERFORMANCE EVALUATION OF "MIDDLE-COMPLEX IMAGE"

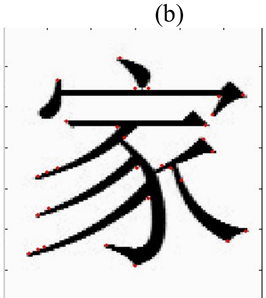
	Harris	KP-Harris	SUSAN	FAST	The proposed method
Correct corners	12	0	12	11	14
Missed corners	0	11	0	3	0
False corners	76	11	47	1	0
Running time(second)	1.334	0.315	6.102	0.586	1.379

(a)

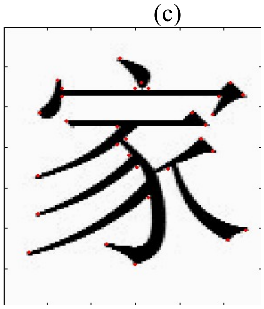
(b)



(c)



(d)



(e)

Fig. 4. Corner detection results for the complex image: (a) Harris, (b)KP- Harris, (c) SUSAN, (d) FAST, (e) the proposed method

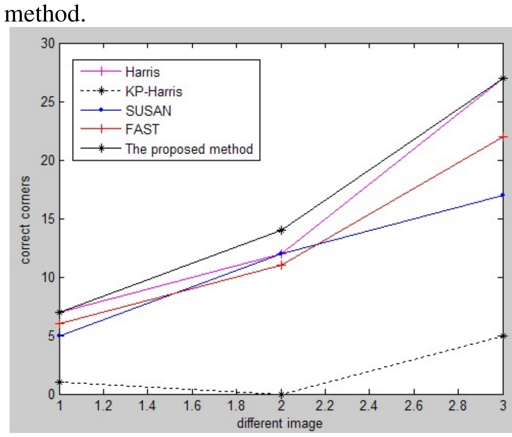
TABLE III. PERFORMANCE EVALUATION OF "COMPLEX IMAGE"

	Harris	KP-Harris	SUSAN	FAST	The proposed method
Correct corners	27	5	17	22	27
Missed corners	0	22	10	5	0
False corners	68	21	30	8	2
Running time(second)	1.638	0.485	5.906	1.366	1.679

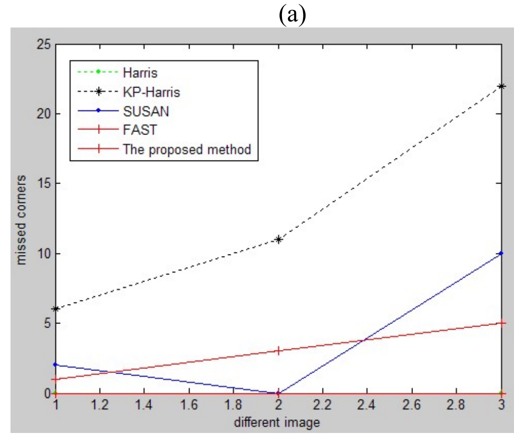
A corner detection algorithm should satisfy the following criteria:

1) *All the corners should be detected*
2) *No false corners should be detected.*
3) *The running time should be short.*

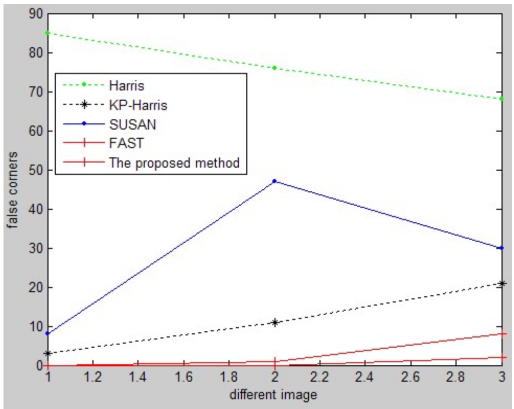
The performance of corner detectors is summarized in Table 1, Table 2 and Table 3. The running time of the FAST algorithm changes sharply with different image. The other methods change weakly. Since running time depends on the image size, we fix image size as 144 by 132. The platform to execute the algorithms is Intel i5 2.5 GH and the algorithms were implemented using Matlab 7.0.1. As shown in Table 1, Table 2 and Table 3, the SUSAN detector is the slowest detector and the KP-Harris method is the fastest detector with lowest detection rate. There is comparison for different algorithm in Fig.5. The running time of the proposed method is rather slower than the Harris, KP-Harris and FAST methods, as shown in Fig.6. However, detection rate is better than any other method.



(a)



(b)



(c)

Fig. 5. Detection rate of different algoithm for different image: (a) Correct corners, (b) Missed corners, (c) False corners

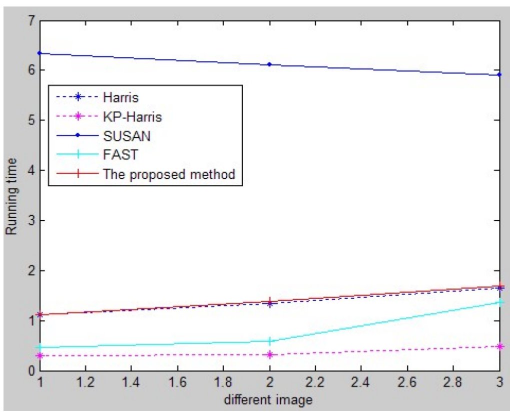


Fig. 6. Running time of different algoithm for different image

V. CONCLUSIONS

In this paper, we improved the Harris algorithm based on FAST. Harris algorithm has correct corners rate, so, firstly be used to detect corners. But false corners rate is large, so, removing false corners accurately is necessary. FAST is suitable to solve it. By reducing computes, running time is better, but not best. In contrast to several methods, the proposed method has best correct corners rate. The experimental results indicate that the proposed method improves detection rate for Chinese characters image. For the further research, we will improve speed of the proposed method.

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